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News Briefs

General Developments

Inquiries about News Briefs, where no contact person is identified, should be referred to the Managing Editor, Journal of Research, National Institute of Standards and Technology, Building 101, Room E215, Gaithersburg, MD 20899-2500; telephone: 301/975-3577.

GUIDE TO CALIBRATION SERVICE FOR CAPACITANCE STANDARDS AVAILABLE

NIST is offering the first publication that provides a comprehensive description of its calibration service for capacitance standards at low frequencies.

These standards are used by industry to calibrate secondary laboratory standards that ensure the quality of various other capacitors contained in electrical and electronic products. Traceability of the capacitance value and/or the uncertainty of the value is important for safety, performance, reliability and stability reasons.

NIST Special Publication 250-47 includes new information, such as improved uncertainties for the NIST calibration of fused-silica capacitance standards, which are gaining widespread use in industrial standards and calibration labs. It also contains material taken from National Bureau of Standards (NIST's predecessor) work dating back to the 1950s.

SP 250-47 can be ordered under stock no. SN 003-003-03549-1 from the U.S. Government Printing Office, (202) 512-1800; or under order no. PB 98-144587 from the National Technical Information Service, (800) 553-6847.

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NEW DIRECTORY LISTS FEDERAL CERTIFICATION AND RELATED PROGRAMS

A newly revised NIST directory, distributed via the Internet, lists Federal certification and related requirements for hundreds of products and services regulated or purchased by 18 federal departments and independent agencies. An update of a 1988 edition, the new directory outlines requirements for items ranging from bottled water to building products, and from nuclear facilities to narcotic test kits and other law-enforcement equipment.

For each Federal program, entries explain its purpose, whether requirements are mandatory or voluntary, and procedures for ensuring compliance and identifying conformance. Additional particulars include agency contact points, authorizing laws and regulations, inspection and testing requirements, sources of documentation, manufacturer or vendor obligations, and reciprocity arrangements.

The intended audience for the directory includes industry, government agencies (Federal, state, local and foreign) and the general public.

The *Directory of Federal Government Certification and Related Programs* is one output of NIST's efforts to build a comprehensive database on U.S. standards, regulations and conformity assessment programs. It can be downloaded from the World Wide Web at http://ts.nist.gov/ts/htdocs/210/217/ 217.htm. Printed copies of the directory will be available later this year. For more information, contact Maureen Breitenberg, Office of Standards Services, NIST, 100 Bureau Drive, Stop 2100, Gaithersburg, Md. 20899-2100, (301) 975-4031, maureen.breitenberg@nist.gov.

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SOLIDIFICATION SENSOR FOR TURBINE BLADE CASTINGS DEVELOPED

Jet engine manufacturers are concerned about the temperature and stress performance of their system's turbine blades. One way to ensure high performance is to monitor the blades as they are being cast to ensure single-crystal growth. NIST has developed a transmission x-ray diffraction sensor that precisely locates the boundary between a liquid metal and a solidifying crystal while they are still in a casting mold.

Although x-ray diffraction monitoring has been tried before, the NIST system is unique because it employs high x-ray energies that can sense the physical state of the casting through a thick ceramic mold and within a vacuum furnace.

NIST has recently published a detailed, illustrated report that describes the sensor system. It covers the theory of x-ray interactions with matter, models of x-ray transmission diffraction, the apparatus used for high-energy transmission diffraction, and describes a number of diffraction experiments.

The project started in 1994 as part of the NIST Consortium on Casting of Alloys, a government-industry-university collaboration with the goal of improving the quality and reducing the cost of aerospace castings through advances in materials science.

For a single, free copy of the report, *High-Energy, Transmission X-Ray Diffraction for Monitoring Turbine-Blade Solidification* (NIST Technical Note 1500-3), contact Dale W. Fitting, MC853.07, NIST, Boulder, CO 80303-3337; (303) 497-3445; dale.fitting@boulder.nist.gov.
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NIST'S RUMBLE ELECTED PRESIDENT OF CODATA

John Rumble, Jr., head of the Standard Reference Data Program at the National Institute of Standards and Technology, was recently elected president of the Committee on Data for Science and Technology. Established in 1966 by the International Council for Science, CODATA seeks to improve the quality, reliability, processing, management and accessibility of data of importance to science and technology.

Rumble has been active in developing scientific database standards, including an international standard for industrial data exchange. He also has helped build several online property data systems.

Further information on CODATA is available on its web site: http://www.codata.org/codata.
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NEW APPARATUS MEASURES THERMAL-BARRIER COATINGS BETTER

NIST researchers have developed an apparatus to measure the thermal conductivity of thermal-barrier coatings (known as TBCs) as thin as 20 μm. TBCs—used in aerospace materials, gas turbine engines and diesel engines—are thermal coatings applied to metal substrates to protect these substrates from high temperatures and excessive wear or corrosion.

Accurate measurement of thermal conductivities is critical before new coating systems can be incorporated into advanced engineering designs and future applications. For example, engineers want to keep lowering thermal conductivities so that TBC thickness can decrease as well.

The NIST device uses an infrared microscope to measure temperature differences on millimeter-sized specimens. The small size of the specimens allows the measurements to be made in air—rather than in a vacuum—which simplifies the apparatus needed. Another advantage is the noncontact nature of the infrared temperature measurement. Any contact between a sensor and a small specimen would affect the specimen's temperature.

For a copy of paper 1-99 describing the thermal conductivity measuring device, contact Sarabeth Harris, MS104, NIST, Boulder, CO 80303-3337; (303) 497-3237; sarabeth@boulder.nist.gov.
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A NOVEL WEAR TESTER FOR BIOMATERIALS EVALUATION

Ultrahigh molecular weight polyethylene paired with an alloy of cobalt and chromium is currently the material of choice for longer lasting orthopedic implants, such as joint replacements for hips and knees. Though this combination of materials has proven to be durable and compatible with the human body, joints made from these components last only about a decade, and the search for better materials is ongoing.

To speed up this process, NIST and four private companies have joined together to design, construct, and test a new apparatus that will reduce the time required for testing of implant materials. Until now, it has, for example, taken about 6 months for conventional equipment to simulate the natural wear of artificial hips.

A computer-controlled wear tester has been designed and built by NIST scientists that has the capability of cross-shearing motions, programmable loading cycles, and spike loads. Using materials of known wear characteristics, a test procedure of 1 week duration has been developed that correctly predicts their ranking. Surface textures and wear debris morphology produced are similar to those from retrieval studies. The current effort involves a test refinement to allow different physiological loading cycles and spikes to be programmed.
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NIST-DEVELOPED VALIDATION SYSTEM FOR TRIPLE DATA ENCRYPTION STANDARD ALGORITHM APPROVED AS AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI) GUIDELINE

In January 1999, ANSI approved the NIST-developed Modes of Operation Validation System for the Triple Data Encryption Algorithm as an ANSI guideline. This guideline, ASC X9 TG.19−Part 1: Modes of Operation Validation System for the Triple Data Encryption Algorithm (TMOVS), specifies the procedures involved in validating implementations of the Triple DES Algorithm in ANSI X9.52-1998, Triple Data Encryption Algorithm Modes of Operation. Those who have implemented the Triple DES Algorithm and are seeking formal validation of their implementation will utilize this ANSI guideline. Successful completion of the tests contained within the TMOVS is required to claim conformance to ANSI X9.52-1998.

The TMOVS specifies individual sets of validation tests, which must be successfully completed to validate an implementation of the Triple DES Algorithm. A separate set of validation tests has been developed for the encryption and decryption processes of each mode of operation.

The TMOVS is composed of two types of validation tests: Known Answer Tests and Modes Tests. The Known Answer Tests are used to verify that implementations correctly implement the components of the Algorithm (e.g., S boxes, permutation tables, etc.). The Known Answer Tests operate on the idea that given known input, a known output must be produced.

The second type of validation test, the Modes Test, verifies that the implementation being tested has not been designed just to pass the Known Answer Tests. A successful series of Modes Tests also gives assurance that an anomalous combination of inputs would not result in an error.

TMOVS testing will be performed as part of the NIST Cryptographic Module Validation (CMV) Program. The CMV Program uses laboratories accredited by NISTs National Voluntary Laboratory Accreditation Program to test cryptographic products that conform to NIST standards. A vendor contracts with an accredited laboratory to perform the tests. After the testing is complete, the laboratory submits the results to NIST for validation. If the vendors implementation of the specific algorithm has passed the tests successfully, NIST issues a validation certificate to the vendor.

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PATENT AWARDED TO NIST SCIENTIST

A patent describing a new lithography process for patterning silicon microchips that uses metastable rare gas atoms for resist exposure was recently granted to a NIST scientist. Metastable rare gas atoms, instead of photons, electrons, or ions, are directed at the surface of a lithographic resist. On impact, the metastable atoms release up to 20 eV of energy per atom into the resist, altering its chemical nature and making it susceptible to etching. The use of metastable rare gas atoms for lithography makes it possible to take advantage of the new techniques of atom optics, which can be used to focus, improve the collimation and intensity of, or modulate the incident atoms. With these techniques, fabrication of features as small as 1 nm might be possible in a parallel process—a goal unattainable by the conventional methods of optical, electron beam, or ion beam lithography. This invention could play a role in solving the sub-100 nm lithography challenge that will be faced by the multibillion dollar microcircuit fabrication industry in the near future.

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PREFIXES FOR BINARY MULTIPLES

The International Electrotechnical Commission (IEC), the leading international organization for worldwide standardization in electrotechnology, recently adopted as an IEC International Standard names and symbols for prefixes for binary multiples for use in the fields of data processing and data transmission. The new prefixes were developed by IEC Technical Committee (TC) 25, quantities and units, and their letter symbols, with the strong support of the International Committee for Weights and Measures and the Institute of Electrical and Electronics Engineers. A NIST scientist, who is a member of Working Group 1 of IEC/TC 25, played a significant role in the development of the prefixes.

Although the General Conference on Weights and Measures has adopted prefixes as part of the International System of Units or SI (the modern metric system) to form decimal multiples and submultiples of SI units, these prefixes represent exact powers of 10. On the other hand, in information technology there is a great need for prefixes for binary multiples, i.e., prefixes to express exact powers of two. The new prefixes for binary multiples are in fact derived from the SI prefixes for decimal multiples. For example, the new prefix for $(2^{10})^1 = 1024$ is called kibi, symbol Ki, which is to be compared with the SI prefix for $(10^3)^1 = 1000$, which is

called kilo, symbol k. Thus one kibibit is written 1 Kibit = 2^{10} bit, while one kilobit is written 1 kbit = 10^3 bit. Similarly, the new prefix for $(2^{10})^2$ = 1 048 576 is called mebi, symbol Mi, which is to be compared with the SI prefix $(10^3)^2$ = 1 000 000, which is called mega, symbol M. Thus one mebibyte is written 1 MiB = 2^{20} B, while one megabyte is written 1 MB = 10^6 B. The other new prefixes are $2^{30} = (2^{10})^3$, called gibi, symbol Gi; $2^{40} = (2^{10})^4$, called tebi, symbol Ti; $2^{50} = (2^{10})5$, called pebi, symbol Pi; and $2^{60} = (2^{10})^6$, called exbi, symbol Ei. These are to be compared with the SI prefixes for 10^9, 10^{12}, 10^{15}, and 10^{18}, which are respectively giga, G; tera, T; peta, P; and exa, E. The new prefixes will eliminate the present confusion between powers of 1000 and powers of 1024 since in the field of information technology the SI prefix names and symbols for decimal multiples are now often used to represent binary multiples.

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MEDICAL PHYSICISTS PUBLISH RECOMMENDATIONS ON RADIOCHROMIC FILM DOSIMETRY

The American Association of Physicists in Medicine Radiation Therapy Committee Task Group has published recommendations on radiochromic film dosimetry. The task group contained three NIST staff members, one of whom pioneered the technique some 30 years ago when he published investigations to determine the dosimetric properties of various forms radiochromic media.

With recent improvements in the sensitivity, accuracy, and precision of radiochromic film manufacturing, as well as the ruggedness and ease of the use of radiochromic dosimeters themselves, such dosimeters have become increasingly popular in medical and nonmedical applications. Over the past several years the dosimetric properties of radiochromic dosimeters have been evaluated by many investigators and an extensive literature on various aspects of radiochromic dosimetry has appeared. The most common form of the media consists of a thin coating, some tens of micrometers thick, on a plastic base material of the order of 0.1 mm to 0.2 mm thick. The initially colorless emulsion turns blue upon exposure to ionizing radiation but is insensitive to room light and requires no processing to fix the image as does conventional x-ray film. The intensity of the color change is proportional to absorbed dose, making it a nearly ideal dosimeter for applications requiring high spatial resolution. At present, various radiochromic dosimeters in the form not only of thin films but also thicker films, gels, liquid solutions, and liquid core waveguides, are used for routine dosimetry of ionizing radiation over a wide range of absorbed dose (0.01 Gy to 1 MGy) and absorbed dose rates (up to about 1 TGy/s). In recent years, various radiochromic dosimeters also have been used for non-clinical applications such as blood irradiation, radiation processing, and as transfer standards.

Until now, there have been no comprehensive guidelines on the use and calibration and associated densitometric systems for clinical use. The report fills the needs of a hospital physicist utilizing radiochromic films for medical applications. The report consists of (1) characteristics of available radiochromic films, (2) procedures for using radiochromic films for dosimetry, (3) characteristics of scanning systems and densitometers, (4) medical applications of radiochromic detectors, and (5) future directions.

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NONDESTRUCTIVE RADIOASSAY TECHNIQUE DEVELOPED BY NIST FOR FLUID-FILLED BALLOON CATHETERS

One of the most active areas in both cardiology and interventional radiology is intravascular brachytherapy (IVBT) for the prevention of coronary restenosis following percutaneous transluminal coronary angioplasty. Because this is a relatively new field of research, many dose delivery systems involving different radioisotopes and devices are under investigation by several research groups. To make meaningful comparisons between these different techniques, it is necessary to have accurate knowledge of the dose delivered to the artery by each system.

An approach being developed by NIST relates the delivered dose to the amount of radioactivity present in the delivery system. To do this, a method has been developed to perform direct and nondestructive measurements of the contained radioactivity in balloon catheter sources. The technique uses a commercially available well ionization chamber ("dose calibrator") and a special radiation shield designed by NIST researchers. The shield was designed to cut all of the radiation emanating from parts of the catheter delivery system except the balloon itself, so that the response of the dose calibrator is due only to the activity contained in the balloon. This system eliminates errors in estimating the contained activity from incorrect assumptions about the catheter dimensions and inhomogeneity of the fluid inside the balloon (i.e., air bubbles).

A necessary part of the development of this system was its calibration, which was achieved for the first test case, radioactive ^{133}Xe gas, using NIST calibrated ampoule sources. A calibration geometry was designed for the system that permits an instrument calibration factor for the balloon catheter to be derived using sources calibrated in a NIST standard geometry. Monte Carlo calculations of the responses in the dose calibrator chamber to ^{133}Xe gas in the standard and modified geometries indicate agreement to within 3 % to 4 %. It is expected that better agreement will be found for radionuclides that emit higher-energy radiations, such as ^{188}Re and ^{186}Re. This technique can be applied in the clinical setting to calculate quickly and accurately administered IVBT doses based on direct activity measurements, increasing the safety and effectiveness of the treatment procedure.

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NIST DEVELOPS GLOW-DISCHARGE RESONANCE IONIZATION MASS SPECTROMETRY FOR MEASUREMENT OF ENVIRONMENTAL RADIOACTIVITY

For many years, NIST has distributed natural-matrix radioactivity standards containing trace amounts of activation and fission products in matrices such as soils and sediments. The extremely low concentrations of radio-nuclides have been measured by sophisticated and time-consuming (1 to 2 weeks for sample preparation) radiochemical analyses, which require the use of solvents for sample extraction. As an alternative method of measurement, NIST physicists have developed a new resonance ionization mass spectrometry (RIMS) system. This system, which uses a glow discharge source and lasers to vaporize soil or sediment containing trace amounts of radioactive materials to be assayed by a magnetic sector mass spectrometer, has been developed to provide a means for establishing radioactive standards in environmental materials useable in clean-up and remediation programs.

The advantages of a glow discharge source are many. The inherent simplicity of source handling and the vast reduction in measurement-time minimize sample preparation error and improve turn-around time in the laboratory. The accessibility for measurement of all mass species and the elimination of some interfering molecular species in the plasma allows for high sensitivity with low background. The possibility of obtaining these high sensitivities combined with the direct interrogation of the source material reduces the need for extraction solvents (with subsequent disposal requirements) since radiochemical processing can be bypassed. Calibration of the system can be obtained by simple isotope dilution of the sample with usually stable, more abundant isotope quantitation of a gravimetrically dispensed master solution.

The system shows great promise in the monitoring of long-lived (half-lives in the range of 100 years or longer) radionuclides in the environment. Typically, for such radionuclides, measurements are required at the 1×10^{-12} level. With the high sensitivity and direct measurement potential of RIMS, this becomes doable without the need to invest an inordinate amount of time in sample preparation or funds on hazardous waste disposal.

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REAL-TIME CHARACTERIZATION OF LITHIUM TRANSPORT IN THIN-FILMS

Thin film "rocking-chair" type cells hold great promise for both "smart window" and rechargeable battery applications by way of reversible ion transfer. Smart windows increase or decrease their light transmission via the application of a small electrical bias and may become extremely important for energy conservation. Windows coated with such films can greatly reduce cooling costs during summer in northern areas, and year round throughout the sunbelt. Lightweight, less toxic lithium-based batteries now dominate the market for laptop computer, cell phone, and other consumer electronics. Market demand for all types of rechargeable cells is expected to grow at a compound rate of 11 % per year, reaching a total of 2 billion cells by 2001, of which the lithium ion cell share is expected to be 440 million cells. Thus the market for lithium ion cells will soon reach about $4 billion. In spite of this rapid commercialization, much of the underlying materials science is not completely understood; such knowledge is necessary to produce better-performing and cheaper products.

Smart windows and many types of lithium batteries consist of two mixed electron/ion-conducting layers separated by an ion-conducting, solid electrolyte layer. Variation in optical density or charge potential is achieved as lithium ions are transported from one layer through the electrolyte to the other layer. The technique of neutron depth profiling (NDP) provides a non-destructive method of measuring the analyte concentration as a function of the depth in the matrix material. NDP has been employed to examine the dynamic lithium distribution in active electrochromic multilayers and has provided insight to the correlation between the device optical density and the lithium transfer between the device electrodes. Measurements made with and

without the electrical bias quantify the migration of lithium as it occurs. The application of these efforts into the area of lithium batteries may explain the reasons for such problems as charge capacity loss with cycling, lower than theoretically attainable reversible charge capacity, and less than theoretically attainable maximum charging and discharging current densities.
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NIST COMMENCES ACCREDITATION/ OVERSIGHT OF COMMERCIAL PROFICIENCY TESTING STUDY PROVIDERS FOR EPA/STATES WATER PROGRAMS

Working with the U.S. Environmental Protection Agency (EPA), states, and other public and commercial entities, NIST has established a system under which private-sector and interested states can be accredited by NIST to provide proficiency testing (PT) services to those laboratories testing drinking water and wastewater for regulated chemical, radiological, and microbiological parameters for EPA and state water programs.

Since the 1970s, EPA has conducted semiannual proficiency testing to assess the competence of more than 8000 public and private-sector laboratories to conduct analyses required by the Clean Water and the Safe Drinking Water Acts. The cost-free provision of these services is being replaced by a multiprovider system in which NIST-accredited state and private-sector entities will provide these PT services on a fee-basis.

NIST NVLAP is accepting applications for accreditation for any of 48 PT program areas in this new field, Providers of Proficiency Testing. Applicants will be assessed for their competence to develop and characterize PT materials and to conduct proficiency test studies. Accredited providers must comply with the requirements of NIST Handbook 150, *NVLAP Procedures and General Requirements* and the newly developed NIST Handbook 150-19, *Chemical Calibration-Providers of Proficiency Testing* for the provision of PT studies that meet the needs described in EPAs "National Standards for Water Proficiency Testing Studies: Criteria Document." In addition, NIST and EPA have worked with the National Environmental Laboratory Accreditation Conference (NELAC) to ensure that the PT studies conducted by the NIST-accredited providers will meet NELAC standards for use in accrediting environmental laboratories.

NIST accreditation and oversight of these providers and provision of Standard Reference Materials to assist in value-assigning PT materials are critical for acceptance of these PT assessments by the laboratories being tested, laboratory accreditation bodies (both private- and government-based), and other interested parties.
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NEW METHOD DEVELOPED FOR ACQUIRING INTERFACE VIBRATIONAL SPECTRA

NIST researchers have developed a new method for acquiring vibrational spectra of interfaces via sum-frequency generation (SFG). Vibrational spectroscopy is a powerful probe for the characterization of structure and chemical bonding; however, conventional vibrational spectroscopies (infrared absorption and Raman scattering) are of limited utility for the study of interfaces due to the presence of large background signals from the bulk material. SFG is a second-order nonlinear optical spectroscopy that is uniquely interface sensitive because SFG mixing is symmetry forbidden in centrosymmetric bulk materials such as liquids, gases, and many solids such as silicon.

The new method developed at NIST involves the interaction of a spectrally broad (500 cm^{-1}), ultrashort (<200 fs) infrared laser pulse with a spectrally narrow ($\approx$4 cm^{-1}) visible laser pulse. Non-linear interactions at an interface result in the generation of a broad sum-frequency spectrum, the entirety of which is detected with a spectrometer equipped with an array detector. This allows acquisition of a spectrum over the 500 cm^{-1} region without tuning the infrared laser or scanning the spectrometer. The new technique has advantages in ease-of-use, spectral quality, and data acquisition rate over the conventional method, which involves the interaction of two spectrally narrow laser pulses and requires tuning of the infrared laser.

SFG vibrational spectra should provide significant insights into critical interfaces, such as those encountered in the study of biological membranes and polymer adhesion, and those underlying the technology of biosensors and advanced semiconductors. The new method was published in the Oct. 15, 1998, issue of *Optics Letters*.
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IRREVERSIBLE MAGNETIC FIELD DEPENDENCE OF THE MAGNETIC STRUCTURE IN GMR Co/Cu MULTILAYERS

Polarized neutron reflectivity (PNR) and scanning electron microscopy with polarization analysis (SEMPA) were used successfully to resolve a controversy involving the giant magnetoresistance (GMR) in Co/Cu multilayers. The GMR in these multilayers makes them very attractive for possible magnetic-field sensor applications.

In general, the magnetoresistance of a GMR multilayer dramatically decreases when an external field reorients the in-plane magnetizations of the ferromagnetic layers parallel to each other. The magnetoresistance is largest for systems in which the low-field resistance is associated with antiparallel alignment of adjacent ferromagnetic layers. For Co/Cu multilayers with thick Cu layers, the magnetoresistance for the as-prepared multilayer is often larger than the maximum obtained after cycling the magnetic field. The magnetic structure corresponding to this large magnetoresistance state has been a puzzle.

Co/Cu samples prepared by a university were analyzed by NIST scientists using both PNR and SEMPA. PNR probes the order of the entire sample and provides a depth profile of the magnetization, while SEMPA produces a direct image of the magnetic domain structure within one magnetic layer at a time. The PNR and SEMPA measurements reveal that as-prepared samples show a strong antiparallel alignment of the ferromagnetic Co domains across the nonmagnetic Cu interlayers. This antiparallel magnetic state is irreversibly destroyed by the application of a magnetic field. After field cycling, the smaller residual peaks in the magneto-resistance are then associated with the presence of small, randomly oriented Co domains.

Using the powerful, complementary tools of PNR and SEMPA, the investigation shows that it should be possible to enhance the performance of these GMR multilayer sensors by stabilizing the initial antiparallel magnetic state.

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EXPERIMENTS SHOW FEASIBILITY OF NEW SCANNING-PROBE MICROSCOPE TYPE FOR HIGH-RESOLUTION IMAGING OF FIELDS ENCOUNTERED IN MAGNETIC RECORDING

NIST scientists have carried out experiments leading toward the development of a new type of magnetic-resonance imaging microscope for applications in the magnetic data storage industry. Applications envisaged for the instrument include meas-urements of fringing fields above the air bearing surface of recording heads, measurements of fields from bits written on recording media, and field mapping on very small scales. The instrument is a scanning probe microscope that measures the magnetic force between a magnetic resonance specimen and a magnetized probe. Several laboratories in the United States and abroad are trying to develop similar instruments, which are referred to as magnetic resonance force microscopes, or MRFMs.

To test the instrument, it is necessary to use a material that has a strong electron spin resonance (ESR) line. The organic compound 2,2-diphenyl-1-picrylhydrazyl (DPPH) is ideal for this purpose. The experimental configuration has a 5 mm DPPH particle mounted on a vibrating cantilever, which, in turn, is positioned near a small permanent magnet probe equipped with a piezoelectric-drive stage. Magnetic resonance is modulated so that the magnetic force between the probe and the particle is at the cantilever resonance frequency. The high mechanical Q of the vibrating cantilever is the key to the unprecedented sensitivity of this technique.

Electron spin resonance spectra were obtained by measuring the changes of the oscillation amplitude of the cantilever as a function of the sweeping background field at fixed points in a plane over the magnet probe. The data then were used to generate magnetic field measurements at each point above the specimen particle. The resonant magnetic field is defined as the product of the resonance frequency and the gyromagnetic ratio of the electron. Both are well-known parameters for DPPH.

The cantilever force is proportional to the product of the DPPH particle magnetic moment and the local magnetic field gradient. The peak cantilever force at resonance is about 1 pN in a field gradient of 100 T/m and an applied field of 30 mT for a 5 μm DPPH particle. This corresponds to the detection of about 10^{10} electron spins in the specimen particle at room temperature. Mechanically softer micromachined cantilevers are expected to provide better force sensitivity, and higher field gradients are expected to improve spatial resolution. The division team expects that combining these features should make it possible to use particles well below 1 μm size at room temperature.

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NIST WORKS WITH INDUSTRY TO ROADMAP INFORMATION TECHNOLOGY NEEDS FOR THE ELECTRONICS INDUSTRY

The National Electronics Manufacturing Initiative (NEMI) is an industry-led consortium of more than 50

manufacturers, suppliers, universities, and federal agencies dedicated to bolstering the national electronics manufacturing supply infrastructure and to facilitating North American leadership in consumer electronics manufacturing. NEMI lays out a research agenda through its suite of technology roadmaps, published every two years, and initiates projects to address identified gaps where no similar efforts exist. NIST has co-led and contributed to several of the working groups that recently published updated Technology Roadmaps. One of the key technologies charted by NEMI is that of Factory Information Systems.

Factory Information Systems (FIS) form the nervous system of a manufacturing facility, analyzing data and delivering information to the machines and people who need it to make information-based decisions. Due to the growing trend by major manufacturers to outsource their operations to first-tier suppliers, a group that is growing at a compounded annual rate of 25 %, information systems are required to interface and integrate with systems outside the four walls of a single organization.

The FIS Working Group identified the following drivers of expanded, distributed FIS capability:

- Shorter production cycle times, higher volumes, and smaller lot sizes mean production managers want and need to manage by exception. However, current FIS products are not integrated and, therefore, cannot provide the timely, integrated factory view needed by managers to take preemptive corrective action.
- Short product life cycles are pressuring manufacturers to move rapidly from design prototypes to volume production, making monitoring and optimizing a new product introduction (NPI) process a high priority.
- Increased outsourcing requires the two-way transfer of manufacturing data between manufacturers and their supply chain. While large manufacturers currently may be able to replicate their suite of in-house FIS applications at their contractors site, replication does not scale to the entire industry and will not remain practical in even isolated cases.

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STANDARDS IN TRADE WORKSHOPS HOSTED FOR LATIN AMERICA

NIST hosted two Standards in Trade Workshops for Latin America last fall. Participants included representatives of Central America, the Caribbean, Belize, Guyana, and Suriname. Twenty-five private-sector and government participants attended the workshop for Central America and the Dominican Republic, held in early fall 1998. Twenty-one participants from the public and private sectors of Antigua and Barbuda, the Bahamas, Barbados, Dominica, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, Suriname, and Trinidad and Tobago attended the workshop for the Caribbean in November 1998.

The agendas for both workshops included briefings and panel discussions with public and private-sector participants, followed by question-and-answer opportunities, NIST laboratory visits, and field visits. Topics included U.S. standards development, product certification, conformity assessment, metrology, laboratory accreditation, the U.S. regulatory process, and the National Center for Standards and Certification Information (NCSCI), which is the U.S. inquiry point for notifying the WTO (World Trade Organization) secretariat of proposed technical regulations that might significantly affect trade and receiving notifications from other countries. Site visits to enhance classroom briefings included a trip to the Fresh Fields Commissary, where participants observed food production and packaging and implementation of the Hazard Analysis Critical Control Point plan, a comprehensive technique to evaluate a food firms ability to produce safe and quality products.

A highlight during the workshop for the Central American group was the NIST-ANSI (American National Standards Institute) Standards Summit held at the Ronald Reagan International Trade Center in Washington, DC on Sept. 23, 1998. The participants in both workshops want future exchanges and focused sectoral workshops, especially in conformity assessment. Invaluable personal and professional relationships were established on which to continue to build trust and from which to draw for future collaboration.
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CRADA SIGNED TO EVALUATE NIST ULTRASONIC TRANSDUCER

NIST has signed a Cooperative Research and Development Agreement (CRADA) with a private company in Hartford, CN. The company is interested in finding practical ways of measuring surface residual stress profiles by nondestructive means. NIST researchers, have developed an ultrasonic transducer that the company believes would be useful for accomplishing this. The CRADA's objectives are to evaluate the utility of the NIST-developed line-focus transducer for the measurement of surface residual stress in an aluminum alloy and to evaluate modifications to the transducer for

improving its sensitivity for detecting such stresses. In return for NIST providing a working copy of its line-focus transducer to the company, it will supply NIST with a set of shot-peened aluminum alloy specimens whose surface stresses have been characterized, by means of destructive profile analyses, on like representative samples. NIST and the company will exchange ultrasonic data obtained on the specimens developed in this program.
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BETTER BOXES MAY MEAN REDUCED FIRE LOSSES

As part of its programs in industrial fire safety systems and material flammability and in cooperation with the American Forest and Paper Association and a private company, NIST is exploring practical means to reduce the flammability of corrugated paper containers used in warehouse storage. Improved fire performance of corrugated paper products may represent a competitive advantage for U.S. paper manufacturers, but it does not drive the industry. The private company is helping NIST evaluate the idea of using nanocomposites to reduce the flammability of corrugated paper while continuing to satisfy the important competitive concerns of the paper industry, which are cost and material properties, such as strength, reducing water uptake in a humid atmosphere, and re-pulpability (for recycling). A number of different clays have been sent to the private company for processing and testing. NIST already is working with the thermoplastics industry, to use clay nanocomposites to reduce the flammability of commodity plastics.
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COLLINS ELECTED ILAC CHAIR

At the annual meeting of the International Laboratory Accreditation Cooperation (ILAC) meeting in Sydney, Australia, last October, Belinda Collins, director of the TS Office of Standards Services, took office as the ILAC Chair. The ILAC members represent laboratory accreditation bodies in some 50 countries, plus three major regional organizations. ILAC aims to achieve globally accepted criteria for the recognition of the competence of accreditation bodies and the development of regional and worldwide mutual recognition arrangements based on the needs of laboratories and their clients and the importance of comprehensive audits and periodic proficiency testing.
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Y2K HELP CENTER IS OPEN FOR BUSINESS

Small manufacturers and other small businesses looking for free help in finding and assessing problems caused by the year 2000 computer problem now can contact the Y2K Help Center for Small Business by calling (800) Y2K-7557 (925-7557), sending electronic mail to y2khelp@nist.gov, or visiting the center's web site at y2khelp.nist.gov.

The Y2K Help Center will provide technical support to users of Conversion 2000: Y2K Self-Help Tool, developed by NIST. The Y2K Self-Help Tool software, available in both Microsoft Access™ and Excel™, can help small businesses conduct an inventory of equipment, identify core business systems and rate their importance to the survival of the business; develop contingency plans; and plan and manage remediation projects. The Y2K Help Center also can provide information on databases of Y2K compliance information.

The Y2K Self-Help Tool is available on the Y2K Help Center web site or from NIST around the country by calling (800) MEP-4MFG (637-4634).
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CONFERENCE GOAL: MAKING THE WEB A LOT LESS TANGLED

Making World Wide Web sites more accessible and more useful to average, nontechnical people has many benefits. For example, companies whose web sites are particularly attractive and easy to navigate often have an advantage over competitors in the electronic commerce arena. In contrast, web sites that confuse customers in a labyrinth of links may lose business to firms with easily traversed pages.

Within an organization, solid web design also makes a difference. Internal web sites where information is easily accessed, understood, and retrieved can help improve employee efficiency, increase production, foster collaboration, and raise morale. Difficult-to-use sites can lead to higher costs, production mistakes and worker frustration.

To address this new area of research, NIST is hosting the Fifth Conference on Human Factors and the Web on June 3, 1999. The theme for the meeting is "the future of Web applications." It will provide a forum for sharing information among a community of human factor engineers, designers, and developers from industry, academia, and government agencies. Among the possible topics for discussion are: usability studies of dynamic, customizable web sites; innovative applications, especially for electronic commerce and enterprise-wide operations; case studies of legacy systems re-engineered for the web; database-enabled sites and

transaction-based applications; usable design with new web technologies such as XML and Java; tools for web usability testing and evaluation; and accessibility.

More information about the conference is available on the web at www.nist.gov/hfweb or by sending electronic mail to hfweb@nist.gov. The final conference program will be available on the web site by April 20, 1999.
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NEW TRANSFER STANDARD IMPROVES CALIBRATIONS FOR OPTICAL METERS

Scientists at NIST have developed and evaluated a transfer standard for the calibration of optical fiber power meters over the wavelength range of 750 mm to 1800 nm. The transfer standard is an optical-trap detector consisting of two germanium photodiodes and a mirror. The photodiodes and mirror are contained in a package that is thermally stable and accepts a variety of optical fiber connectors. Benefits of this transfer standard versus previous standards include high optical-to-electrical conversion efficiency, reasonable cost and improved spatial uniformity.

As a transfer standard, the detector is robust and convenient to use in different laboratories, the scientists report. They will continue to evaluate the standard to establish a calibration history and to determine the effects of aging on the photodiodes and mirror.

More information on the standard is available from John H. Lehman, (303) 497-3654, lehman@boulder.nist.gov. A paper, no. 2-99, explaining the standard is available from Sarabeth Harris, MS104, NIST, Boulder, Colo. 80303-3337; (303) 497-3237; sarabeth.harris@nist.gov.
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NIST SCIENTISTS DEMONSTRATE HIGHLY DIRECTIONAL ATOM LASER

Atoms in a Bose-Einstein condensate can be manipulated with light to form a highly directional atom laser, NIST physicists reported in the March 12, 1999, issue of *Science*. The NIST device represents a significant step forward from the first atom laser demonstrated in 1997 in that its atoms stream forward in a chosen direction as a very narrow beam. The direction of the earlier atom laser beam was determined by gravity and had a large spread due to the tendency of the atoms to repel each other.

"The atom laser is as different from an ordinary atom beam as an optical laser is from a flashlight. It now gives you for atom beams what you have had with laser light," says Nobel Laureate William D. Phillips, leader of the Laser Cooling and Trapping Group in the NIST Physics Laboratory.

Although practical uses of the atom laser could be years away, scientists are excited about the NIST invention and its potential. Researchers anticipate being able to create holographic images producing any picture or pattern desired on a flat surface. This eventually may lead to improvements in lithography, the manufacturing technique for making exquisitely small features on computer chips.

For more information and to see images of the atom laser, go to the NIST Physics Laboratory's news page on the World Wide Web at www.physics.nist.gov/atomoptics.
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DOORS OPENED TO NEW CHEMISTRY BUILDING AND NIST'S FUTURE

NIST took its first step into the 21st century with the March 8, 1999, dedication of the new Advanced Chemical Sciences Laboratory (ACSL) in Gaithersburg, MD. The $75 million, 18 588 m^2 (200 000 ft^2) ACSL—the first major construction in nearly 40 years at the Maryland site—was built to house the research programs of NIST's Chemical Science and Technology Laboratory (CSTL).

Research by CSTL scientists long has benefited our Nation's health and environment, as well as industrial productivity and international trade. The new state-of-the-art ACSL features advanced designs that will help NIST meet 21st-century needs for accurate chemical measurements, standards and methods used for pharmaceutical manufacturing, medical diagnosis, pollution monitoring and clean up, nutritional analysis, and other chemistry-related endeavors.

Among the features of the ACSL are 162 laboratory modules that can be reconfigured to meet special needs, 131 office modules, precise temperature and humidity control, high-capacity ventilation systems, an uninterruptible power supply, a high-purity water system, five clean rooms, two cold rooms, five non-metallic labs, and advanced data transmission wiring.
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1999 NATIONAL INFORMATION SYSTEMS SECURITY CONFERENCE

Computer experts from around the globe will converge in the Washington, DC, area this fall to address the hottest information security issues of the approaching millennium.

The 22nd National Information Systems Security Conference, co-sponsored by NIST and the National Security Agency, is expected to attract more than 1600 participants. The annual conference is one of the largest and most significant computer security gatherings in the world. Expected to draw a wide range of industry and academic participants as well as government experts, the conference will take place at the Hyatt Regency Crystal City in Arlington, VA, Oct. 18-21, 1999.

Panel discussions and papers will cover a diverse set of topics such as electronic commerce, Internet security, research and development, security testing and evaluation, and public key infrastructure technology. Conference goals include educating participants about major information security issues and provoking debate and action on these issues.

More information about the conference is available at http://csrc.nist.gov/nissc.

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NIST PROPOSES TRIPLE DES

On Jan. 15, 1999, NIST published a *Federal Register* announcement that proposes changes to the existing Federal Information Processing Standard (FIPS) 46-2, Data Encryption Standard (DES), to recommend the use of a stronger technique to protect sensitive, unclassified information, known as Triple DES. Triple DES is a method of using the DES algorithm in three operations, which will provide the additional security needed for federal applications. It is specified in American National Standards Institute (ANSI) Standard X9.52. In addition to the adoption of Triple DES, the proposed FIPS 46-3 recommends that:

- For existing systems, government organizations are encouraged to migrate to Triple DES based on a prudent strategy that matches the strength of the protective measures against the associated risk; and

- New procurements should use Triple DES. Information on Triple DES may be found at http://www.nist.gov/encryption. A 90 day public comment period for the approval of the proposed revised standard closed on April 15, 1999.

The Data Encryption Standard was first adopted in 1977 as FIPS 46 for the encryption of sensitive, unclassified computer data. The standard was reaffirmed in 1983, 1987, and 1993 as FIPS 46-2 and has been used to protect Federal Government information and, on a voluntary basis, many private-industry applications. As technology has advanced, the relative strength of DES has declined, thus highlighting the need to find a replacement. Therefore, in 1997, NIST initiated the design and development of the Advanced Encryption Standard (AES). Completion of the AES will require a substantial amount of time; final approval is not expected until 2001. See http://www.nist.gov/aes for information about the AES development.

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NIST FACILITATES DEVELOPMENT OF ELECTRONIC BOOKS

NIST is playing a pivotal role in the continuing saga of electronic books. An electronic book is a portable device that integrates display, microprocessor, and storage technologies resulting in a reading appliance with significant functionality over paper-based books. NIST developed a prototype electronic book that incorporates desired functions like font resizing, touch-screen control, electronic dictionary, and voice activation. Last fall, NIST hosted the worlds first conference on electronic books, which attracted more than 400 attendees ranging from publishers, electronic book manufacturers, display fabricators, software developers, and end users. Members of the industry met to form the Open Electronic (E-Book) Standards Committee; NIST was asked to assist in this effort.

In January 1999, NIST co-organized the first working meeting of the Open Electronic Book Standards Committee, which met in San Francisco. The purpose of the meeting was to review and comment on a draft specification. Specific topics discussed at the meeting centered on the adoption of an XML-HTML common format, the use of standardized metadata, and the ability of the standard to adopt future multimedia components, e.g., picture (jpeg, bmp), and video file formats. Participants agreed that the proposed straw-man draft needed further review, and the industry requested NIST to head an authoring group to review the scope and purpose of the proposed standard. NIST offered the use of its prototype electronic book as a reference implementation once the standard is finalized. The Open E-Book Standards Committee agreed to meet again in the spring of 1999. NIST also participated with the Electronic Book

Exchange Group (EBX) that is developing standards for copyright protection of electronic content as it is transmitted from publisher to e-book holder.

NIST continues to conduct further research with its prototype, looking to integrate writable DVD storage, thus giving the electronic book full multimedia capabilities. Also, the NIST prototype will incorporate speech, making it a "talking book."

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INDUSTRY SUCCESSFULLY EVALUATING FIREWALL PRODUCTS BASED ON PROFILES DEVELOPED BY NIST AND THE NATIONAL SECURITY AGENCY (NSA)

Two private companies have successfully completed evaluations of their firewall products against version 2.0 of the Common Criteria, an international standard (ISO 15408) for security evaluation criteria. Both products demonstrated compliance to the Common Criteria as well as to the Federal Governments family of firewall protection profiles. As a result, these products received Common Criteria certificates at the recent RSA Data Security Conference in January 1999, marking the beginning of a new standard of quality for this product class. Other firewall vendors are expected to undergo product evaluation and receive a similar certificate in the near future. An estimated 60 % to 75 % of the collective firewall market share is represented by the products that have completed evaluation or are in evaluation. Firewalls serve as part of an organizations overall security defense by isolating an organizations internal network from the Internet or other external networks.

Jointly representing the United States, NIST and NSA were among the original six national sponsors (United Kingdom, Netherlands, France, and Canada) of the Common Criteria, and under the National Information Assurance Partnership (NIAP) developed the Governments firewall protection profiles. More information on the Common Criteria and NIAP can be found at the following web sites: http://csrc.nist.gov/cc/, http://www.radium.ncsc.mil/tpep, and http://niap.nist.gov.

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NIST'S INTERACTION AUTOMATION SOFTWARE USED AT THE SOUTH POLE

Expect, NIST's interaction automation software, is in use at the South Pole (www.spole.gov) through the National Science Foundations SPIREX (South Pole Infrared Explorer) and Australias AASTO (Automated Astrophysical Site-Testing Observatory). Experiments at the pole are difficult and expensive but significant due to unique conditions—for instance, the extreme cold means that the sky is much darker in the infrared wavelengths and the dryness means that there is little water vapor to absorb interesting wavelengths. Since living conditions are harsh, the goal is to build an observatory that needs no human intervention to run for a year at ambient temperatures down to –80 °C. Expect facilitates this goal by allowing control of astronomical equipment via embedded controllers over the Internet. Pictures of the site are available at http://www.phys.unsw.edu.au/~mcba/aasto.html. Expect is in use at a number of other observatories around the world such as Siding Spring Observatory and Kit Peak National Observatory.

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COMPUTER MODEL PREDICTIONS AID IN DECISION TO IGNITE SHIP

Predictions from a computer program developed by NIST fire researchers were used to evaluate the impact of intentionally igniting the fuel on the *New Carissa,* a freighter grounded on the coast of Oregon. Igniting the fuel on the ship could reduce the quantity of oil reaching the water and impacting natural resources and wildlife in the area. The National Oceanic and Atmospheric Administration response team on site requested predictions from ALOFT-FT™, which was developed specifically for situations involving the intentional burning of oil spills. The predictions gave authorities confidence about the limited spread of the downwind smoke plume over populated areas. ALOFT-FT™ provides detailed three-dimensional predictions of the downwind distribution of smoke particulate and combustion products from large outdoor fires. The ignition of the fuel on the ship was the first use of intentional burning of oil at sea off the coast of the continental United States and the first use of ALOFT-FT™ in response to an incident. Photographs of the smoke plume from the ship fire agree favorably with the predictions from the model.

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A NEW LUBRICANT CONCENTRATION MEASUREMENT TECHNIQUE FOR POOL BOILING

NIST scientists have demonstrated the feasibility of a new in situ technique for measuring the concentration of lubricant on a boiling heat transfer surface. The proposed technique relies on the fluorescence of the lubricant to determine the amount of lubricant that has

accumulated on the heat transfer surface. Fluorescence occurs when the incident light is at a shorter wavelength than the light emitted from the surface.

The heat transfer performance of a boiling surface in refrigeration equipment is a strong function of both the type of lubricant and its concentration in the refrigerant. After boiling of the refrigerant, excess lubricant resides in a very thin layer on the surface. Severe boiling performance degradation can occur in evaporators when high concentrations of lubricant reside in a very thin layer on the surface. In measurements of 10 lubricant samples in special test equipment, researchers found that lubricant concentration on an aluminum "stepped" target surface was a linear function of fluorescence intensity and the reflected harmonic from the surface. The next step of the research will be to test the concept on an existing pool boiling rig using a bifurcated optical bundle with both excitation and emissions detection in a single cable. The goal of the research is to enable manufacturers to chose lubricants that both lubricate the compressor and improve the heat transfer performance of the evaporator.

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ANALYZING NEUTRON POLARIZATION WITH POLARIZED ^{3}He

NIST researchers recently demonstrated polarization analysis on the NG3 Small Angle Neutron Scattering (SANS) spectrometer using polarized ^{3}He gas. Polarized ^{3}He analyzers (and polarizers) rely on the large spin dependence of the cross section for absorption of neutrons by polarized ^{3}He gas. Cold and thermal neutrons are excellent probes of materials. They penetrate matter much more than charged particles, and their wavelengths are well matched to the characteristic size and dynamics of atoms.

The NIST polarized ^{3}He program includes two different optical pumping methods of producing samples of ^{3}He gas with spin-polarized nuclei: spin-exchange and metastability-exchange. To simplify this test experiment, cells full of polarized gas were prepared by each method and transported to the SANS instrument. Because polarized gas is sensitive to magnetic field gradients, the cells were transported in a battery-powered solenoid and another solenoid was used at the SANS instrument. The polarization was sufficiently large and long-lived to permit a demonstration of a classic use of polarization analysis: separating coherent scattering from incoherent scattering.

This proof-of-principle experiment was the first application of polarized ^{3}He to neutron scattering in the United States. Further development and successful application of polarized ^{3}He spin filters also could have a profound impact on the currently planned Spallation Neutron Source (SNS) at Oak Ridge National Laboratory. Polarizing monochromators are used at reactor sources for polarizing thermal neutrons, but a broadband polarizer such as polarized ^{3}He is better suited to the pulsed neutron beams produced by spallation sources because neutron energy information is extracted by time-of-flight. The next step for the NIST researchers is to use polarization analysis techniques to separate magnetic and nuclear scattering.

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ANALYZING IMAGES FROM NEAR-FIELD OPTICAL MICROSCOPY

NIST researchers have developed accurate, efficient, computational models for understanding and analyzing images made by near-field optical microscopy (NSOM). NSOM is being studied intensively in two NIST competence programs to achieve optical spatial resolution much better than the diffraction limit. To do so, nanometer-scale apertures and sharp tips are used to localize probe fields. The improved spatial resolution is realized when the sample is placed in the probe near-field. However, strong near-field coupling between the sample and probe greatly complicates image analysis. Detailed modeling is required to understand images and clearly separate probe and sample contributions to these images.

NSOM is a challenge to model. Electromagnetic field propagation and scattering is modeled on length scales that must cover two to three orders of magnitude to include all processes that affect image formation. The researchers have developed models and algorithms that are powerful enough to capture the essential physics of image formation, yet are still computable in reasonable times. They have used these models to analyze NSOM images made in collaboration with researchers at the Naval Research Laboratory, and two universities. As described in a recent *Physical Review B* publication, they have developed analytical models to analyze images made of nanochannel glass arrays. Modeling the entire process of image formation is critical for correctly interpreting the images. The researchers find that the NSOM images reveal detailed information about the photonic modes of these glass arrays. In another study,

they have used the coupled dipole approach to model NSOM images made of Au nanoparticles. These images reveal detailed information about the fields near the end of the NSOM probe. Such information is a critical input for modeling other images made with these probes. The images in these two examples provided very different information. Modeling was necessary to successfully extract the content of these images.

Currently, the NIST researchers are extending this work to improve the models and enhance the efficiency of the algorithms. They now are using these models to better understand imaging of thin films, including biological and polymer films, refractive index profiling, and imaging of optical waveguides, routers, and couplers.

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NIST ADVANCED RADIOMETER SELECTED FOR NASA'S TRIANA MISSION

Two NIST scientists have been selected to lead the development of a spaceflight instrument, the Scripps-NIST Advanced Radiometer (NISTAR), which is scheduled to fly as part of the National Aeronautics and Space Administration's (NASA) Triana Mission. The Triana spacecraft is expected to be launched in September 2000 aboard the space shuttle and subsequently will be placed in an orbit about L1 (the Lagrange libration, or neutral gravity point between the Earth and the Sun), about 1.5×10^6 km from Earth. At that position, an imaging camera and NISTAR will have a continuous, nearly full disk, sunlit view of the Earth. NISTAR will make measurements of the reflected solar and emitted thermal radiation from the Earth. These measurements will be traceable to NIST's HACR (high-accuracy radiometer), the Nations primary standard for optical power measurements. NIST is working with a private company to develop the NISTAR instrument to meet the science requirements of the Scripps Institution of Oceanography, University of California at San Diego, and install the Triana spacecraft at NASA's Goddard Space Flight Center in Greenbelt, MD.

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HIGH PRECISION AND SENSITIVITY ACHIEVED USING MIDINFRARED CAVITY RINGDOWN SPECTROSCOPY

In a collaborative effort, scientists from NIST and a university have developed a high sensitivity and high frequency precision absorption technique based on the observation of saturation dips in the midinfrared using cavity ringdown spectroscopy (CRDS). CRDS has generated much recent interest for sensitive concentration measurements of trace contaminates in gas samples and for the absolute measurement of very small molecular absorption cross sections. The absorption cell in CRDS consists of a confocal Fabry-Perot optical cavity made of very high reflectivity mirrors, which allow effective optical pathlengths on the order of kilometers to be achieved. Previously, the technique had been based in the near-infrared and visible spectral regions where high-reflectivity mirrors and a variety of tunable lasers are available.

A midinfrared cavity ringdown spectrometer has been developed by using a tunable laser based on nonlinear mixing of a CO_2 laser and microwave radiation in a CdTe modulator. The midinfrared region of the spectrum offers significant advantages for CRDS since virtually all molecules strongly absorb in this spectral region. The scientists have taken advantage of these large absorption strengths to observed nonlinear saturation of a transition with the technique. The nonlinear absorptions have linewidths on the order of 1 MHz, or less, or approximately 2 % of the full Doppler width. The technique also offers potential analytical chemistry applications, since saturation signals were observed using gas partial pressures as low as 0.004 Pa. Potential applications include the absolute measurement of the absorption cross sections for unstable molecules and characterization of the atmospheric water continuum.

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FIRST ACCURATE VACUUM UV REFRACTIVE INDEX MEASUREMENTS OF CALCIUM FLUORIDE

NIST researchers have made the first and only accurate measurements of the index of refraction, its dispersion, and its temperature dependence of calcium fluoride in the vacuum ultraviolet near 157 nm. These results were presented at the International SEMATECH 157 nm Workshop in Phoenix, AZ, in February 1999. These measurements are crucial for the design of optical systems for 157 nm excimer-laser-based optical lithography tools, which are projected to be used for the fabrication of future-generation integrated circuits (around 2005). Since these are the only measurements available, all major semiconductor lithography companies in the United States, Europe, and Japan are using these results in their optical designs.

The index measurements were made by the minimum deviation method with a relative uncertainty of 10^{-5}, using a precision goniometer in a nitrogen purge atmosphere. The dispersion was determined using line emission radiation near 157 nm from a deuterium lamp, with

wavelengths calibrated using a vacuum ultraviolet Fourier-transform spectrometer. Temperature control of the sample and surrounding medium to 0.05 °C enabled an accurate determination of the temperature dependence of the index.
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A FREE-FALL DETERMINATION OF *G*, THE NEWTONIAN CONSTANT OF GRAVITATION

Determinations of *G*, the Newtonian constant of gravitation, initially seen as a way to measure the mean density of the Earth, go back to Isaac Newton. Yet after hundreds of years of research, the relative uncertainty with which this fundamental constant is known is surprisingly low—only 1.5×10^{-3}. A few years ago, a carefully carried out measurement of *G* reported a number that disagreed with the accepted (CODATA) value by more than 40 standard deviatons. In the hope of addressing this inconsistency, NIST scientists devised a novel new approach to the problem—an approach that resulted in the only laboratory measurement of *G* using an unsupported test mass. They used a well-characterized 500 kg tungsten standard of mass (in the shape of a ring) to either increase or decrease the rate of fall of a small test body dropped in a vacuum. By measuring the acceleration difference for these two cases, they obtained a new value for *G*. Their value, which has a relative uncertainty of 1.4×10^{-3}, lies 1.5 times the value's uncertainty above the CODATA value. Since this result was reached using a completely new method, this agreement should help rule out the possibility that previous meas-urements suffered from some common systematic bias.
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HEXAPOD KINEMATIC ERRORS REDUCED

Rapid production of quality contoured parts requires machine tools that combine speed, accuracy, stiffness, and multiaxis versatility. A new class of parallel-actuated machine tools based on the Stewart platform mechanism presents new possibilities for meeting these needs; however, much remains to be learned about the characteristics of these "hexapod" machine tools before they will see widespread production application. Thus, in May 1995, NIST researchers began working with one of these machines.

Extensive simulation and iterative characterization tests were necessary to identify its most significant errors. The main difficulty is that in a parallel-actuated machine, such as the Hexapod, there is not a one-to-one correspondence of an observed error to a single problem. In other words, the measured error map does not offer many clues as to the source(s) of error.

It was therefore necessary to develop several simulation tools, as well as the required Hexacluster metrology instrument, to carry out the studies. An active Hexapod Users Group has been incorporating NISTs knowledge base into tools and procedures for this new class of machine tools. One such development has been a new test part analogous to the circle-diamond-square, expressly designed for traditional machine tools. Both this test part and the calibration procedures are forming the basis for new standards and inputs to the ISO 230 and ANSI/ASME B5 committees.
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NIST RESEARCHERS DEVELOP ADVANCED MICROMACHINING PROCESS THAT ALLOWS COMPANIES WITHOUT ON-SITE FABRICATION FACILITIES TO MANUFACTURE MEMS

NIST and an industrial partner have developed a new silicon micromachining process to fabricate CMOS microelectromechanical systems (MEMS). The new process enables companies that do not have on-site integratd circuit (IC) fabrication facilities to fabricate CMOS MEMS structures. Such structures vary widely, ranging from micro-heating elements for micro-hotplate gas sensors and thermal flat panel displays to passive microwave components for microwave coplanar transmission lines and power sensors. One major advantage of the process is that it provides improved understanding and control of silicate chemistries in the use of tetramethylammonium hydroxide (TMAH) to anisotropically etch (micromachine) silicon. The researchers found that the process was remarkably sensitive to reagent concentration and needed extensive laboratory development. Another major advantage of the process is that it preserves exposed metallization at wire bond pads over very long periods of etching time, which, in turn, means higher yield and increased compatibility with a production environment.

CMOS MEMS are manufactured in commercial IC processes. The IC process creates device structures (precursors) that are then processed into the final MEMS structures. The TMAH process is cleaner, safer, and easier to implement than the ethylenediamine pyrocatechol (EDP) process commonly used to perform the post-process function.
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EXPERIMENTAL RESULTS DEMONSTRATE THAT POWER ELECTRONIC INTERCONNECT PARASITICS CAN BE ACCURATELY CHARACTERIZED WITH TIME DOMAIN REFLECTOMETRY

Recent experiments by a NIST scientist have demonstrated, for the first time, the use of time domain reflectometry (TDR) to characterize the interconnect parasitics of a prototype power converter. The components of this prototype high-power inverter include insulated gate bipolar transistor (IGBT) power modules, a busbar, and a high-voltage dc capacitor. The experiments proved that the internal interconnect impedances of the IGBT module can be extracted completely using TDR. Results also indicated that the busbar can be modeled by uniform transmission line segments between connection points, and that the dc capacitor contained a significant series interconnect inductance. Moreover, the TDR method also may be used to characterize any other power electronics devices or components, such as the interconnects for microprocessor power-supply regulators.

Without adequate metrology for characterizing interconnects, the electromagnetic wave propagation properties of interconnects are often approximated using analytical or computational methods that do not adequately predict the nonideal behavior of real interconnects. These methods have some fundamental limitations because the physical properties, parameters, and structures of the conductor materials are not generally known, and assumptions must be made in computations.

A measurement-based method such as TDR is critical for the characterization of the transmission line properties of the interconnect parasitics because they cannot be considered as ideal lumped elements (resistors, capacitors, inductors), but must be represented as distributed transmission line elements having transmission line characteristic impedances and propagation delays. In addition, the transmission line characteristics typically are not uniform along the interconnect and must be represented using several transmission line segments having different characteristic impedances and propagation delays.

The electrical behavior of module and circuit board interconnects is also becoming increasingly more important in determining the behavior of digital and analog systems due to the increasing speed and power requirements and decreasing operating voltages. A major impediment to the development of the next-generation microprocessor modules is the lack of power-supply stability caused by the interconnects between the microprocessor chip, its power-supply bypass capacitor, and its power-supply voltage regulator. The primary reason for this is that power requirements have changed; the power-supply voltage has changed from 3.3 V for present systems to 1.1 V for future systems, the voltage compliance requirements have changed from 5 % for current systems to 2 % for future systems, and the requirement for rate-of-change of power-supply current during power-up has changed from 1 A/ns to 5 A/ns. Given that the characteristic impedance is a key parameter in the present and next generation voltage regulator design, improved interconnect metrology is essential.

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ITERATIVE IR APPROACH FOR EXTRACTING VALUES OF INTRINSIC OPTICAL CONSTANTS OF SILICON REDUCES UNCERTAINTY BY A FACTOR OF 10

Infrared (IR) spectroscopy is a powerful technique that has been used extensively by industry to analyze a variety of materials, but, up to now, the use of IR probes to characterize semiconductor materials has been limited by a lack of reliable optical data, models, and test methods. Of these limitations, the most critical is the lack of accurate values for the intrinsic optical constants, $n(\omega)$ and $k(\omega)$, for silicon. At present, the published values of $n(\omega)$ possess relative uncertainties of about 10^{-3}, while the reported values of $k(\omega)$ vary by a factor of 2 or even greater, in some cases.

NIST researchers have developed a new iterative method that leads to a reduction in the uncertainty of $n(\omega)$ by a factor of 10. Using this method, the uncertainty of $k(\omega)$ is also significantly reduced. Further, the measurements have brought to light a systematic error in the published values of $n(\omega)$, which could be a significant source of error in prior IR analyses.

The method developed by the researchers extracts accurate values for the midinfrared (450 cm to 4000 cm^{-1}) optical constants, $n(\omega)$ and $k(\omega)$, of silicon. Two Fourier transform infrared (FTIR) spectra were used: a high-resolution spectrum ($\Delta\omega = 0.5\ cm^{-1}$) yielding a typical channel spectrum, dependent mainly on the sample thickness and $n(\omega)$; and a low-resolution spectrum ($\Delta\omega = 4.0\ cm^{-1}$) yielding an absorption spectrum, dependent mainly on the sample thickness and $k(\omega)$. Independent analyses of each spectrum gave initial $n(\omega)$ and $k(\omega)$ estimates. The estimated values then were used as the starting point for an iterative fit of the high- and low-resolution spectra successively. The improved accuracy of the values for the intrinsic optical constants will allow semiconductor manufacturers to

further refine the IR spectroscopic analytical limits for impurities and thin insulator layers needed to produce larger and more tightly specified 300 mm wafers.
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INTERNET-BASED TEST SERVICE ENABLES CUSTOMERS TO INTERACT WITH NIST STAFF WHILE CALIBRATIONS ARE PERFORMED

Multifunction calibrators, which are used to test and verify the accuracy of digital multimeters (DMMs), are used in a wide variety of industrial applications. In many cases, these calibrators require traceability to nationally and internationally accepted electrical standards. Like DMMs, calibrators operate over a wide range of ac and dc voltage, current, and resistance, and it is virtually impossible to test all available output signals. In the past, several approaches have been devised to test these instruments reliably and efficiently.

One approach is to calibrate them using a few electrical-standard artifacts and rely on self-calibration software in the calibrator to compensate for errors over the entire operating range. Another approach is to calibrate as many points as possible (more than 200) using standard artifacts (Zener references, resistors, and thermal converters), and then interpolate between points to estimate uncertainties over the operating range. Most users are more comfortable with the second method, but, even with semi-automated systems, it can take a skilled technician up to a week to complete such a test. A third approach, one that is gaining popularity, is to use a transportable DMM that has been characterized using an artifact-calibrated calibrator or reference calibrator maintained at a national laboratory or an accredited standards laboratory. This approach limits the laborious artifact calibrations to a few laboratories with the time and resources to devote to the task. Traceability is provided through a test report for the transportable DMM.

A new service is evolving at NIST that offers significant value-added benefits to the latter approach. Most important of these is that a customers calibrator can be monitored by NIST staff as the test is performed at the customers site. The new service will employ the Internet to expand present capabilities, making the process not only more efficient and less time consuming but also more collaborative. A customer-owned DMM will be tested using the customers test calibrator, shipped to NIST where it will be tested using a NIST reference calibrator, and returned to the customer for follow-up tests. An interactive Internet link between NIST and its customers will be established to improve communications, enable rapid transfer of test data, and allow the customer to download test protocols and software for system evaluation.

With both audio- and video-capability, NIST will be able to provide real-time consultation and assist with troubleshooting during the test. The customer's "before" and "after" data will be sent electronically to NIST where the data analysis will be performed. Once completed, a password-accessible report (that expresses the test calibrator errors and uncertainties in terms of the NIST reference calibrator) may be posted on a NIST web site. In addition, an interactive database of test systems with historical data and instrument modeling should make it possible to predict performance (based on periodic comparisons between the customers calibrator and DMM), to increase or extend the calibration interval, and to update the test report. If successful, this approach could be applied to many other areas of measurements at NIST and throughout the metrology community.

This work also is tied closely to the Interamerican Metrology System Network (SIMNET), a new program to use the Internet to enhance international comparisons of measurement standards within this hemisphere.
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REFRACTIVE INDEX PROFILING OF OPTICAL FIBERS AND PLANAR WAVEGUIDES WITH UNPRECEDENTED RESOLUTION

NIST scientists have built and demonstrated a refracted near-field (RNF) system, which measures with exceptional resolution, the two-dimensional refractive index profile in both optical fiber and planar waveguides. The RNF technique probes a waveguide with 635 nm laser light focused to a point on the entrance face of the waveguide. The waveguide is placed in contact with a material of nearly equal refractive index, allowing light to escape from the side of the waveguide. Measuring the power of the escaping light gives a precise measurement of the index of refraction at the focal point of the launched light. The relative uncertainty of this technique is generally limited by the uncertainties of the calibration artifacts to about 10^{-3} to 10^{-4}. However, the researchers are able to make measurements with a repeatability of 4.3×10^{-5}. This is about an order of magnitude smaller than the resolution achieved in other published RNF results.

Since the lightwave propagation in a waveguide depends on the index of refraction profile within the guide, it is important to have an accurate knowledge of

the details of that profile. The RNF technique allows a waveguide manufacturer to verify that the manufacturing process yields the expected profile or to quantify the outcome of a new fabrication technique. For example, this RNF system is being used currently to measure index profiles of ion exchange waveguide structures to determine the diffusion coefficient of the dopant ions into the waveguide.

To the waveguide designer, the index profile measurement provides the propagation characteristics of the guide and allows theoretical performance to be compared to measured results. Index profile measurements facilitate accurate waveguide modeling, which in turn improves waveguide performance and manufacturing yield. For example, a particular area of interest among manufacturers is the ability to measure residual strain in the waveguide. Residual strain can affect the index profile or it can alter the polarization of the light; in either case, it will have a deleterious effect on the performance of the device. RNF measurements offer the possibility of mapping the strain-induced birefringence in the waveguide by controlling the polarization state of the input light. The NIST RNF system is being modified to allow these measurements as well.

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NEUTRON SCATTERING REVEALS THE MECHANISM BEHIND THERMAL CONTRACTION

At the NIST Center for Neutron Research (NCNR), scientists from NIST, a university, and a private company are exploring the atomic structure and dynamics of the rare examples of solids that contract upon heating. Engineers always have been forced to contend with unwanted thermal expansion of solids. Railroad engineers got around the problem by leaving spaces between tracks, but in modern information technology tolerances are much tighter and this necessitates a search for materials whose dimensions do not vary with temperature. One way to accomplish this is by combining materials with opposite coefficients of thermal expansion in suitable ratios to form composites with temperature-independent dimensions. Unfortunately, almost all solids expand with temperature and very few contract over a significant temperature range.

ZrW_2O_8, a material that does contract with increasing temperature, consists of octahedral and tetrahedral metal oxide molecules, that form an open and highly under-constrained structure. Neutron scattering revealed a very low energy molecular twist mode, which is a consequence of this structure and which causes thermal contraction because twisting molecules tug on their surroundings. ZrW_2O_8 already is being used by the private company to compensate thermal expansion in fiber-optic gratings. The discovery of the mechanism behind this effect was possible only through the use of neutrons and state-of-the-art instrumentation as is available at the NCNR. This work will help to identify other substances that can be used to produce composites that have no thermal expansion for applications where thermal expansion cannot be tolerated.

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OPTICAL SPECTROSCOPIC METHOD FOUND USEFUL IN DETERMINING PHASE SEPARATION IN INDIUM GALLIUM NITRIDE FILMS

A new generation of short-wavelength, blue to ultraviolet, light-emitting devices is being developed from thin films of the group III nitrides, AlN, GaN, InN and their alloys. These devices will be used for applications ranging from high-density optical data storage systems to outdoor lighting and instrument panels. The active region of a typical blue-emitting nitride thin film device consists of a stack of ultrathin (2 nm to 4 nm) indium gallium nitride ($In_xGa_{1-x}N$) layers, alternating with GaN, and sandwiched between thicker (100 nm to 1000 nm) GaN layers. Since the wavelength of the emitted light is determined by the indium fraction, control of the alloy composition is critical to producing devices with reproducible, optimal properties. Composition control is difficult, however, because alloys in the InN-GaN system have a tendency to phase separate by spinodal decomposition at the typical film growth temperatures of 600 °C to 800 °C. Raising the growth temperature is not feasible, because, at higher growth temperatures, sufficient indium cannot be incorporated into the $In_xGa_{1-x}N$ layers.

Although these films are intended for optical applications, little work has been done to examine the effects of phase separation and compositional inhomogeneity on their optical properties. In a collaboration with a university scientist, NIST researchers are using several optical spectroscopic methods to examine films with indium amount of substance fractions from $x = 0.06$ to $x = 0.50$. Using optical transmittance, photoluminescence

excitation, cathodoluminescence, and Raman spectroscopy, they have found that the different optical probes respond differently to the compositional changes, but that all of the techniques suggest the presence of increased inhomogeneity and, possibly, multiple phases as the indium fraction increases. These results suggest that optical spectroscopic methods can provide a simple (in terms of sample preparation) and nondestructive probe of the occurrence of phase separation in $In_xGa_{1-x}N$ layers.

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PROCEEDINGS OF THE NATO- AND NIST-SPONSORED MEETING ON DNA DAMAGE AND REPAIR PUBLISHED

The book containing the proceedings of the recent NATO- and NIST-sponsored meeting on "DNA Damage and Repair; Oxygen Radical Effects, Cellular Protection and Biological Consequences," has been published by Plenum Publishing Corp., New York.

This meeting, also called a "NATO Advanced Study Institute," was organized by Miral Dizdaroglu of CSTL'S Biotechnology Division and took place in Antalya/Turkey on Oct. 13-24, 1997. It was sponsored by NATO, NIST, and, in part, the Danish Center for Gerontology, Scientific and Technological Research Council of Turkey and the Turkish Society of Toxicology. The meeting was attended by 37 invited lecturers from NATO countries and Japan as well as 75 other participants from 23 different countries, including NATO countries and NATO Cooperation Partner countries such as Russia, Bulgaria, Romania, Poland, Lithuania, Ukraine, and Armenia. The volume is entitled "Advances in DNA Damage and Repair; Oxygen Radical Effects, Cellular Protection and Biological Consequences." It contains 37 chapters written by well-known international experts and encompasses the state-of-the-art knowledge and recent developments on various aspects of oxidative DNA damage and its cellular repair and on the pertinence of this research field to human health. Further, more than 80 abstracts of the works presented during the meeting by the participants as oral contributions or papers are included.

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Standard Reference Materials

NIST STANDARD REFERENCE MATERIAL (SRM) USED BY THE INTERNATIONAL ATOMIC ENERGY AGENCY TRAINING PROGRAMS

Radionuclides have permeated and resided in the environment since the formation of the Earth, and, in general, human radiation exposure from this primordial radioactivity does not cause untoward human health risk. However, enhanced release of radionuclides into the environment through human action can result in addi-tional and meaningful radiation exposure that has significant financial consequences and impact on human health. In these elevated radiation areas, it is necessary for environmental management to assess accurately the damage, develop cost-effective remediation strategies, evaluate the effectiveness of the remediation activity, and monitor the cleaned-up site into the future. To make this possible, NIST has gone to enormous efforts to develop natural matrix environmental radioactivity SRMs, which can be used in the determination of radioanalytical performance.

Many labs have helped NIST certify 13 nuclides in the natural matrix SRM, Rocky Flats Soil (SRM 4353). Soil SRMs, such as Rocky Flats, are important because they are representative of desert soils and have minimal, yet measurable, quantities of plutonium isotopes. As various national and international agencies have better defined their roles in environmental remediation and compliance activities, there has been a growing need to train personnel in proper radioanalytical techniques and to demonstrate the quality of analytical data. The International Atomic Energy Agency (IAEA) laboratories in Seibersdorf, Austria, which conducts training programs for radiochemists from member states, recently held a training program for radiochemists from various countries, and SRM 4353 was used as a test analyte by the students.

NIST continues to collaborate with the IAEA laboratories—most recently in development of Ocean Sediment SRM 4357. This will provide a convenient material in training radiochemists in radionuclide measurements in marine sediments, another potential concentration "sink" for radioactive contamination.

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Standard Reference Data

NEW INFRARED SPECTRAL DATABASE INTRODUCED TO SUPPORT REMOTE SENSING APPLICATIONS

NIST researchers recently developed NIST Standard Reference Database 79 (SRD 79) "Quantitative Infrared Database," which contains absorption coefficient data for 21 hazardous air pollutants. Over the last decade, growing concerns about the environment in general and air quality in particular have stimulated the development of improved, cost- effective field monitoring methods. In Fourier transform (FT) infrared-based technologies developed for real-time monitoring of airborne chemical contaminants, an infrared source is aimed at a retro-reflector placed at some distance away, and the resulting reflected beam is passed through an FT spectrometer. Multiple compounds can be measured simultaneously—because each molecular species has a unique infrared spectrum—with sensitivities at the 1×10^{-9} level. The in situ and real-time nature of this approach offers several advantages over traditional point source monitoring techniques for applications such as determining fugitive emissions and chemical contaminants from industrial processing plants, hazardous waste and municipal landfills, water treatment plants, oil refineries, and chemical plants. Following successful testing of FT infrared methods during remediation of several Superfund sites, the U.S. Environmental Protection Agency (EPA) has issued a protocol (TO-16) for FT infrared open-path remote sensing. Successful implementation of this protocol is highly dependent on the availability of high-quality reference spectral data from a definitive source since molar absorptivity data in the literature widely differ.

SRD 79 data are based on NIST primary gravimetric standards prepared with starting materials of assessed purity and procedures that minimize contamination. The initial 0.12 cm^{-1} resolution data were processed to generate data at a number of different resolutions and apodizations to provide users with data that closely match their experimental parameters. SRD 79 data are provided in a standard JCAMP-DX format on a CD-ROM. A digital signature accompanying each data file allows users to ensure the integrity and source of the data file and traceability to NIST. Intercomparisons with a number of expert laboratories, including the National Physical Laboratory of the United Kingdom, were used to assure the quality of the NIST data. Future plans are to expand the intercomparisons of NIST primary standards and molar absorptivity data with additional national metro-logy institutes to facilitate the use of this database in issues of global interest and impact.

The current version of SRD 79 can be obtained through the NIST Standard Reference Data Program. At its completion, this database will include many additional compounds listed in the EPA Clean Air Act as well as those that are of concern in global warming and emissions trading issues. Updates to the NIST SRD 79 will be available over the Internet as additional spectra are added.

A validated quantitative database traceable to national measurement standards is a critical part of the infrastructure required for establishing emerging infrared-based monitoring technologies. This new FT-infrared technology, coupled with the NIST spectral database, provides both industry and EPA with a tool for assessing regulatory compliance that is both cost effective and less invasive.

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NIST RESEARCHERS DEVELOP STANDARD REFERENCE DATA FOR IMPORTANT PLASMA PROCESSING GAS

NIST researchers recently completed the determination of a set of standard reference data for electron interactions with chlorine gas (Cl_2). This gas is of significant technical importance to the semiconductor industry where it is used in various etching processes to fabricate microelectronic devices. Many reactor models have utilized electron collision cross sections for Cl_2 that were based upon a cross section set derived more than 10 years ago. This set has been shown to contain significant inaccuracies.

The standard reference data for Cl_2 derived at NIST were determined from a thorough assessment of the electron interaction data available in the scientific literature. This is the sixth gas to be investigated in an ongoing NIST project to provide reliable electron interaction data to the semiconductor industry. The data assessment for Cl_2 was particularly complex because of the large amount of data in the literature and the questionable reliability of much of the data due to the reactive properties of the gas. The reference data for Cl_2 contain cross sections for total electron scattering, momentum transfer, total vibrational excitation, electronic excitation, total dissociation into neutrals, total ionization, total electron attachment, and ion-pair formation. Reference data for various electron transport parameters also were determined, along with electron

interaction data with other species commonly found in Cl_2 plasmas, such as Cl, Cl^+, and Cl. These new reference data provide a sound basis upon which plasma modelers can base their calculations. The reference data will be posted on the World Wide Web for easy access by industry.

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DATABASES NOW ON THE JOB TO HELP KEEP GAS FLOWING

Engineers in the natural gas industry will be interested in a new paper from NIST that describes three computerized databases which provide thermophysical properties for pure fluids, mixtures of fluids, and a predictive package emphasizing hydrocarbon systems.

The pure fluids database, known as the NIST12 Database, includes natural gas components such as methane, ethane, propane, and *iso*- and *n*-butane. Each fluid is represented by a highly accurate equation of state; correlations also are provided for viscosity, thermal conductivity and dielectric constant. A separate program for helium covers both the superfluid and normal fluid states. The DOS-based, interactive database is menu driven and user friendly.

The NIST14 Database provides accurate thermophysical properties of 17 pure fluids and their mixtures. This database emphasizes accurate density calculations, yet provides excellent results for other properties. NIST has been working on new models for mixture properties, and these will be incorporated into future versions of NIST14.

The NIST4 Database (NIST SUPERTRAPP) emphasizes prediction of thermophysical properties for a large number of fluid systems that have not been adequately measured to establish standard property surfaces. The interactive, DOS-based database allows calculations for 192 pure fluids and their mixtures of up to 20 components. The fluids include hydrocarbons up to carbon-24, as well as common impurities such as carbon dioxide, nitrogen, oxygen, and hydrogen sulfide. The FORTRAN source code for property prediction also is included, so that a user may link it with other software.

Copies of the databases may be ordered from the Standard Reference Data Program, NIST, 100 Bureau Dr., Stop 2310, Gaithersburg, MD 20899-2310; (301) 975-2208; srdata@nist.gov. Copies of paper 3-99 explaining the data-bases are available from Sarabeth Harris, MS104, NIST, Boulder, Colo. 80303-3337; (303) 497-3237; sarabeth.harris@nist.gov.

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